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A Computer-Based Acoustical Measurement System For NASA Glenn Research Center

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1. INTRODUCTION

The NASA Glenn Research Center's Acoustical Testing Laboratory (ATL) was designed from the ground up for noise emission testing of International Space Station (ISS) components. This specialized facility requires an equally specialized data acquisition and analysis system. Challenges include:

- short equipment uptime due to ground support equipment limitations,
- multiple test article configurations and operational modes,
- special test requirements specific to ISS flight hardware,
- flexibility to accommodate future testing requirements,
- highly variable environmental noise conditions,
- rapid decision making and report generation, and
- tight integration with other laboratory functions.

A custom acoustical measurement system has been developed that addresses the challenge of short operational periods through multi-channel real-time analysis/display and rapid auto-ranging. A unique feature of this system is its ability to continuously monitor and assess potentially intrusive exterior noises. Special tools are included for capturing time waveforms, performing high-resolution narrowband analysis, and creating audio files. Perhaps the most important feature is that the system is "open": ATL owns a license to the source code and is able to adapt as needed.

2. HARDWARE

The system is currently configured for 18 channels but is expected to grow over time. A system diagram is presented in Figure 1. Microphones and preamplifiers are connected to B&K 2822 Multiplexers which provide signal conditioning and the opportunity for charge injection calibration. The multiplexer function is not used at this time; individual channel signals are passed through to the data acquisition boards.

Data acquisition and analysis are performed by National Instruments NI-4551 and NI-4552 Dynamic Signal Analysis boards. These boards have two and four input channels, respectively, along with an onboard DSP. Special DSP code is loaded at initialization that allows the boards to perform one-third octave, linear-weighted, A-weighted and A-weighted impulsive analysis for all channels to 10 kHz, or one-half the channels to 20 kHz. Analysis results are retrieved by the host computer on a continuous basis. The boards can be laboratory calibrated by a third party. In effect, each channel is an independent single channel real-time analyzer.

The advantages of this arrangement are significant. Resource-intensive analysis takes place at the board level, so the host computer is freed to focus on test management and data display. Other applications on the host computer do not affect data analysis, only its transfer and display. Significant timing-related data integrity problems that can occur when the host computer oversees the data acquisition are virtually

eliminated. In this way, high channel count is achieved without impacting data integrity or real-time display and control.
The MAGMA P13R 13-slot PCI expansion chassis makes all boards accessible to the host computer through a single PCI-bridge card. The potential channel count of this chassis using NI-4552 boards is therefore 52. An additional advantage is that the considerable heat load of the boards is transferred to the expansion chassis from the host computer.

Temperature, humidity and barometric pressure are monitored continuously and are transmitted on demand to the host computer through a GPIB bus.

3. SOFTWARE

NI SPS v1.1

The core of the measurement system software is the National Instruments Sound Power System v 1.1 (SPS) running under National Instruments' LabVIEW 6i. SPS provides a comprehensive platform for performing noise emission testing in a free-field environment. SPS handles documentation, test configuration, microphone calibration, automated sound power calculation in accordance with all current standards, and export of data to template reports in Excel. SPS is unique in that it can be purchased with source code, which makes possible all of the following modifications.

Multi-channel Extension

Nelson Acoustical Engineering, Inc. developed a Multi-channel Extension (MCE) for SPS that permits simultaneous measurement of all configured channels. The purpose of the MCE is to maximize throughput and ease the task of dealing with large amounts of data. This is especially important in light of the short uptime of some experimental packages.

A sample from the MCE display is presented in Figure 2. A single channel display permits viewing data from any individual channel in the conventional manner. NC curves and user-programmable spectra are provided as reference spectra to aid in comparing data to NASA criteria.

The multi-channel displays provide graphical representations of the data to facilitate rapid identification of differences between channels. The color map (shown) represents frequency along the x-axis, position number along the y-axis, and one-third octave band level as color. This helps identify spatial variations in noise emission as well as the occasional channel fault or bad connection. For instance, the color map in Figure 2 shows at a glance that Position 5 is disconnected and, when viewed in color, that Positions 2 and 4 have the most energy around 1 kHz.

The system auto-ranges automatically, continuously, and simultaneously on all channels, and is therefore always ready when the Start button is depressed. For most sources, all channels are successfully ranged in a few seconds. This minimizes both ranging "surprises" from time-varying signals as well as the delay that might ensue from ranging after pressing "Start". Individual overload indicators are provided for each position.

If the measurement is suspended before reaching its full duration the operator has the option of saving the data anyway. This helps in the event that ground support equipment (e.g., bottled gases) gives out unexpectedly or in the event of an impending noise intrusion.

Noise Intrusion Monitoring

Aircraft taking off from Cleveland Hopkins Airport, ground support equipment, and other activities in ATL's host building are potential causes of noise intrusion. The acoustical test chamber is of single wall construction, so the possibility of exterior noises influencing the data cannot be ignored. Given the potential for limited duration of ground support, it is not satisfactory to assume that a measurement could simply be repeated. The Noise Intrusion Monitoring feature was added to MCE to provide a real-time method of determining if noise intrusions increase measured results by a pre-determined amount. This prevents retesting "just to be sure" and ensures that excessive ambient influence on measurements does not go unnoticed.

Two monitoring microphones are provided for: one atop the laboratory Control Room and one within the Control Room (which serves as a noise control enclosure for ground support equipment). The sound pressure levels inside the chamber due to intrusive noise are estimated from the levels at the monitor microphones and the noise reduction of the test chamber. Indicators are activated if the intruding sound levels approach the measured ones too closely in any band.

Calibrated WAV Files

The value of listening to sounds during acoustical measurement cannot be overstated. Similarly, describing test results is often very effective through the medium of digital audio files.

Standard audio files such as .WAV are intrinsically uncalibrated because they do not make reference to the gain settings along the signal chain. However, by calibrating the signal chain and then assigning a normalization value for use on playback or analysis, a calibrated signal can indeed be stored in a WAV file. With the addition of this feature to the MCE, recording of calibrated audio files is only a few keystrokes away during any measurement. See Figure 3.

High Resolution FFT Analysis

FFT analysis is most commonly used in noise emission testing for source identification. One limitation with conventional analyzers is that they are often limited to 800 or 1600 lines, leaving the operator with the choice of either poor frequency resolution or laborious use of Zoom FFT.

A software module was added to MCE that captures the pressure signal from selected channels simultaneously. See Figure 4. The operator may then further cull the selected channels and trim the time signal before performing FFT analysis. The FFT analysis is performed in software by the host computer and is therefore not subject to the common 800- and 1600- line limitations. Several seconds of data are sufficient to provide resolution better than 1 Hz. See Figure 5. The operator may then graphically zoom in on interesting portions of the frequency spectrum before saving the trimmed time and/or trimmed frequency data directly to a specific cell and sheet in an Excel worksheet.

4. CONCLUSION

The ATL measurement system is a customized computer-based measurement solution tailored to the needs of the laboratory. Its chief advantages are:

- Real-time multi-channel data acquisition, analysis and display
- Rapid and robust auto-ranging
- Customized analyses and displays
- Tight integration with Excel worksheets
- System can be modified as needs change

Weaknesses in computer-based measurement systems arise chiefly from the structure of the Windows operating system environment. Changes to operating system, device drivers, software versions, file

structures, etc. can cause problems that wouldn't normally be seen on a packaged analyzer. Nelson Acoustical Engineering is currently evaluating the benefit of PXI computers (i.e., dedicated PC-compatible measurement platforms) that minimize the impact of the operating system on the measurement process.

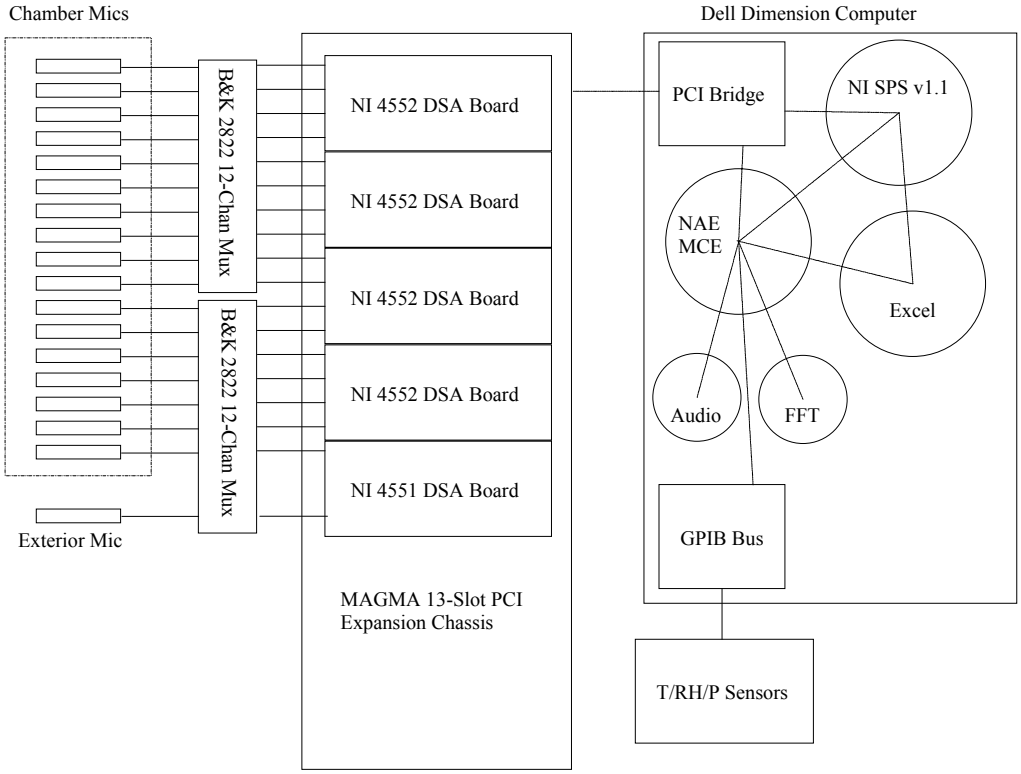

Figure 1: Measurement System Block Diagram

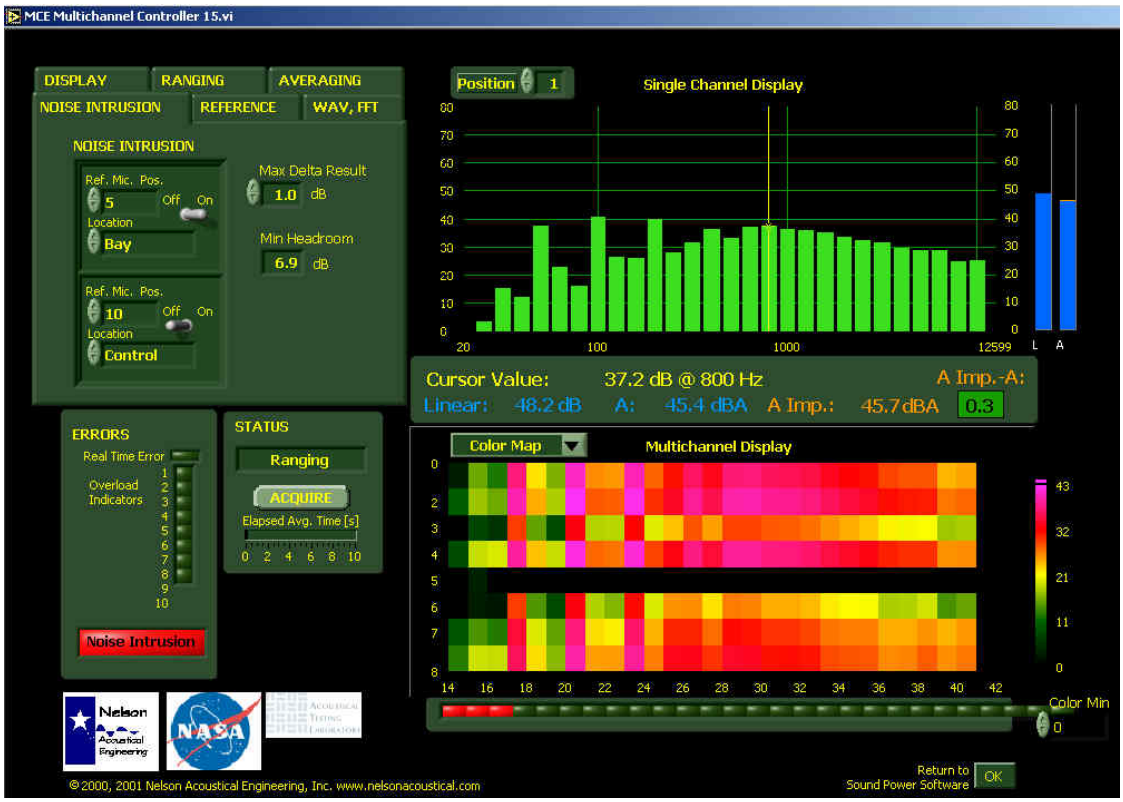

Figure 2: MCE Display

Figure 3: WAV File Display

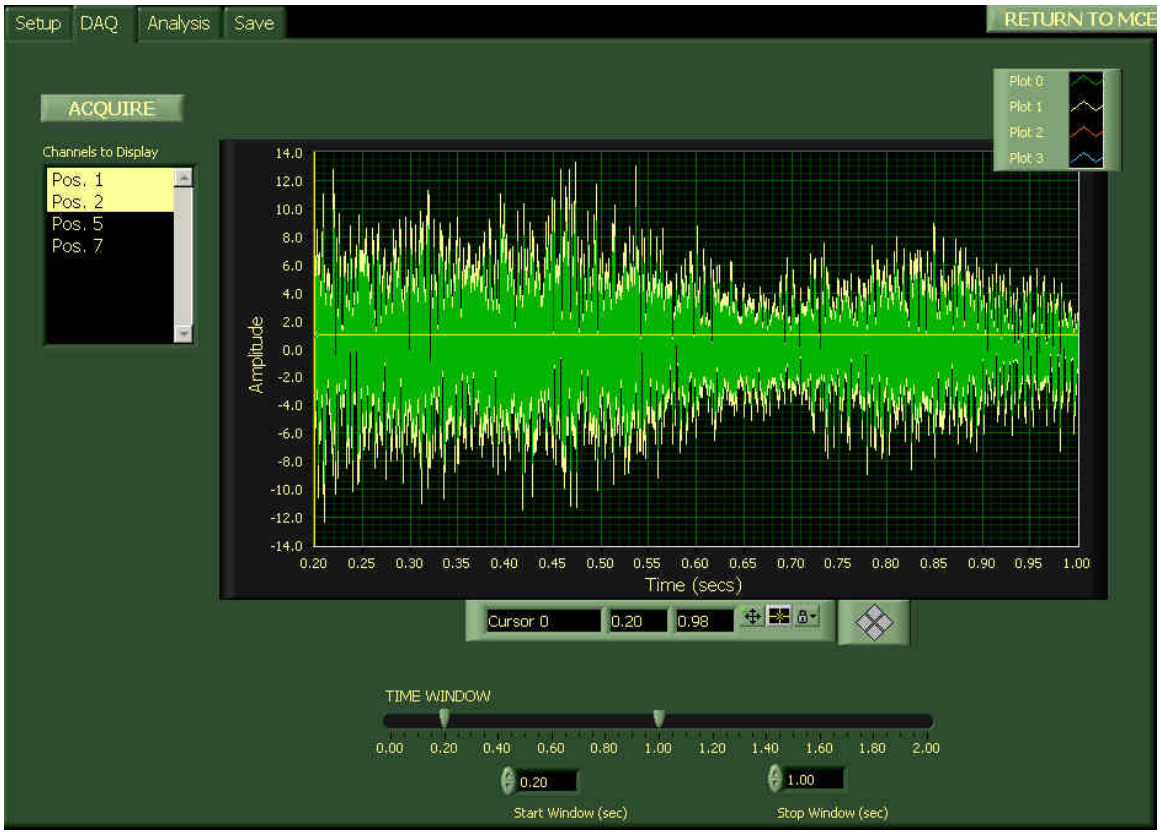

Figure 4: Time Capture Display

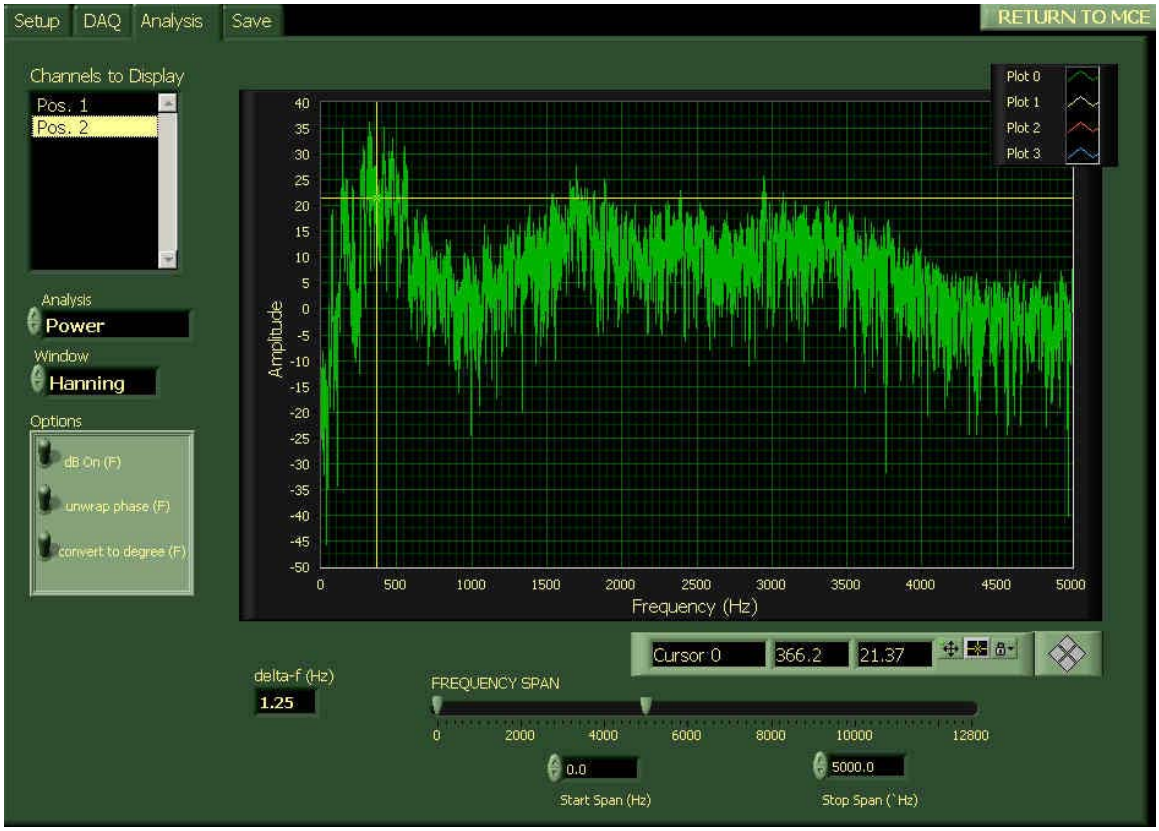

Figure 5: High-resolution FFT Display